Estimation of Ocean Surface Wind Speed and Direction from Polarimetric Radiometry Data

David R. Lyzenga
Department of Naval Architecture and Marine Engineering
University of Michigan
2600 Draper Road
Ann Arbor, MI 48109-2145
phone: (734) 764-3216   fax: (734) 936-8820   email: lyzenga@umich.edu

LONG-TERM GOALS

To develop improved methodologies for estimating ocean surface wind vectors from polarimetric microwave radiometry data.

OBJECTIVES

To evaluate a proposed algebraic method for correcting microwave radiometry data for atmospheric effects, and for estimating the wind speed and direction from the corrected data.

APPROACH

Various combinations of the vertically and horizontally polarized brightness temperatures have been examined, using simulations based on a two-scale model (Lyzenga, 2006), in order to determine their dependence on the atmospheric water vapor and liquid water content as well as the surface wind speed. These predictions are compared with actual WindSat data, and used to provide an indication of the wind speed that is independent of atmospheric conditions. A second set of equations is used to calculate the wind direction from the third and fourth Stokes parameters.
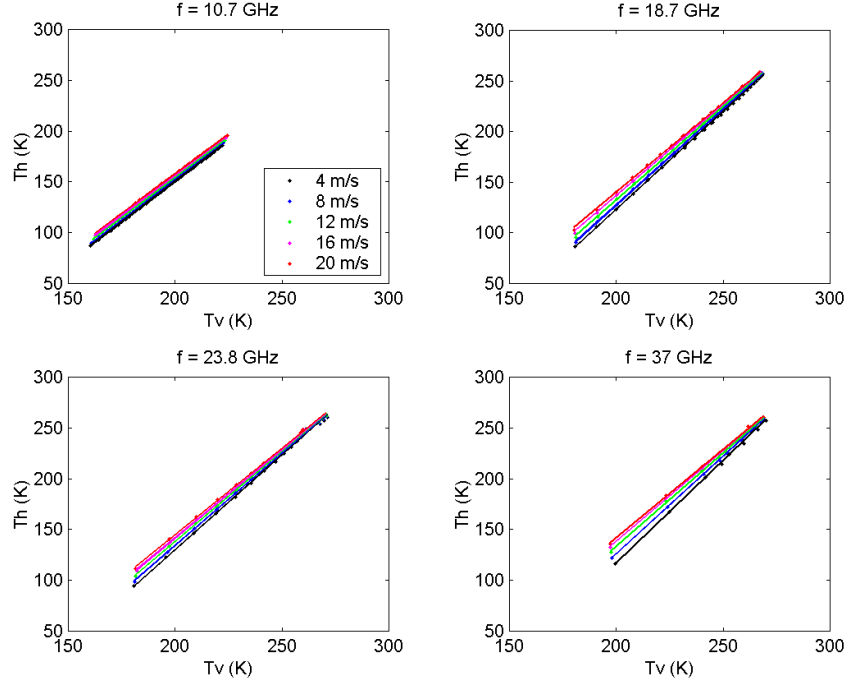
WORK COMPLETED

A wind vector algorithm has been proposed on the basis of two-scale simulations, and preliminary tests have been carried out two WindSat data sets. Several additional data sets have been acquired and are currently being used to further test and refine the proposed algorithm.

RESULTS

Plots of the simulated brightness temperatures over a range of wind speeds and atmospheric variables are shown in Figure 1. The ratio $R = (T_v - T_{vo})/(T_h - T_{ho})$ was found on the basis of these simulations to be nearly independent of atmospheric effects, and to be linearly related to the wind speed. Plots of R versus the wind speed are shown in Figure 2.

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Figure 1. Horizontally polarized brightness temperature, T_h , versus vertically polarized brightness temperature, T_v , for a range of wind speeds and atmospheric parameters (water vapor and liquid water content) as calculated using a two-scale model (Lyzenga, 2006).
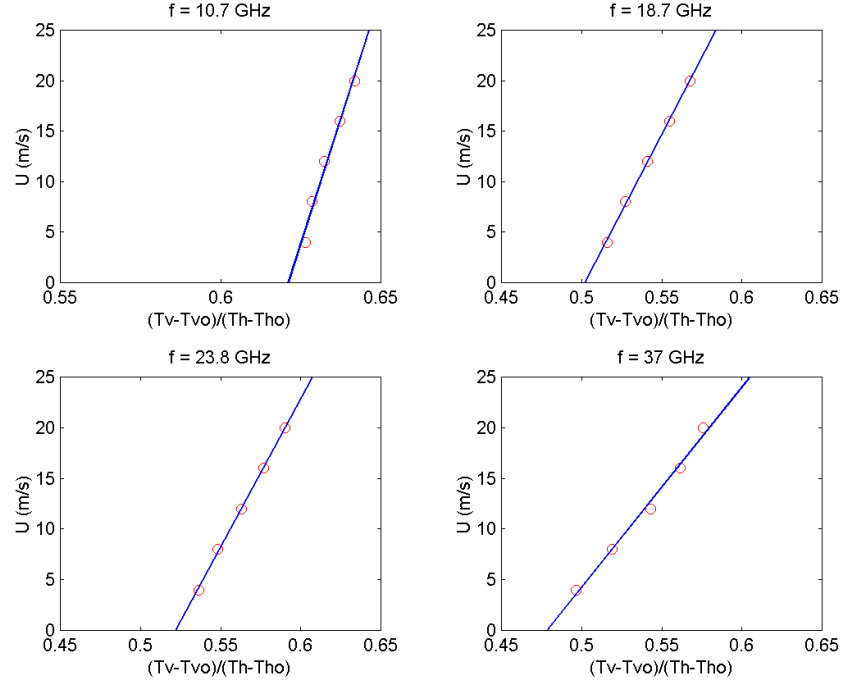
Figure 2. Relationship between the wind speed and the ratio $R = (T_v - T_{vo})/(T_h - T_{ho})$ for four WindSat frequencies.

These relationships allow the wind speed to be calculated as $U_w = u_0 + u_1 R$ where u_0 and u_1 are functions of the microwave frequency. This equation was used to calculate the wind speed from the 18.7, 23.8, and 37.0 GHz WindSat bands (the dependence at 10.7 GHz was found to be too weak to be useable), and the results from these three bands were averaged together.

Two methods have been used to calculate the wind direction. The first method obtains the wind direction (ϕ_w) by solving the equations

$$U = U_1 \sin\phi + U_2 \sin(2\phi) \quad \text{and} \quad V = V_1 \sin\phi + V_2 \sin(2\phi)$$

for $\phi = \phi_w - \phi_s$ where ϕ_s is the scan angle, U and V are the third and fourth Stokes parameters as observed at the scan angle ϕ_s, and U_1, U_2, V_1, and V_2 are coefficients calculated from the two-scale model. The second method solves the equations

$$U_f = U_1 \sin\phi_f + U_2 \sin(2\phi_f) \quad \text{and} \quad U_a = U_1 \sin\phi_a + U_2 \sin(2\phi_a)$$

where U_f and U_a are observations of the third Stokes parameter from the fore and aft scan angles ϕ_f and ϕ_a respectively. Details of these algebraic solutions are given in Kim and Lyzenga (2008).

Example results are shown, and compared with nearly coincident QuikScat winds, in Figures 3 and 4. Figure 3 shows the wind vectors calculated from the WindSat data collected over Hurricane Dean at 21:24 UTC on 16 August 2007, and the corresponding QuikScat data collected at 21:58 UTC on the same day (from ftp://podaac.jpl.nasa.gov/pub/ocean_wind/quikscat/L3/data). The wind directions for this case were obtained by averaging the results from the two methods described above in the overlap region between the fore and aft swaths. Figure 4 shows a similar comparion between the WindSat data collected over Hurricane Ike at 10:26 UTC on 6 September 2008 and the Quikscat data collected at 10:46 UTC on the same day. The wind directions shown here are from method 2.
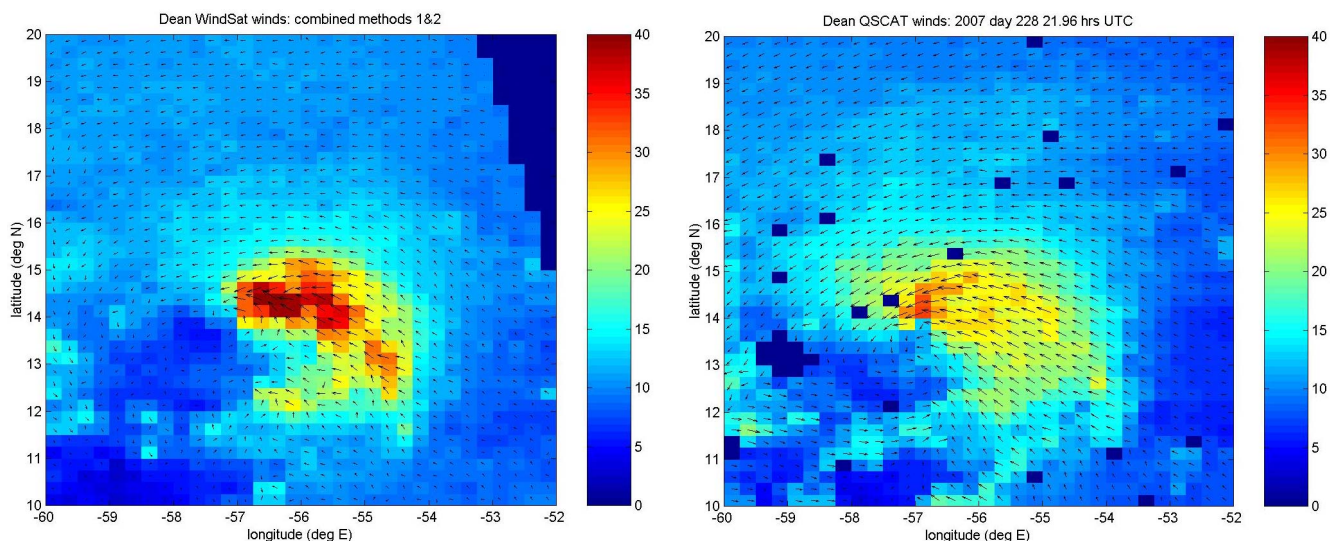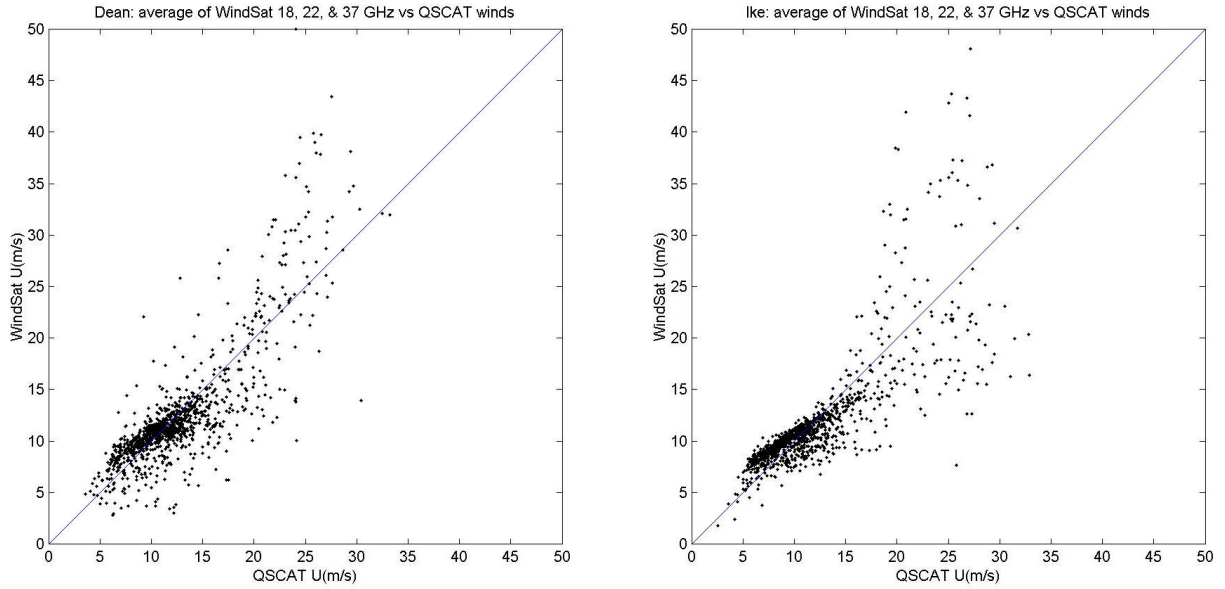
***Figure 3. Comparison of WindSat and QuikScat wind vectors for Hurricane Dean,
on 16 August 2007.***
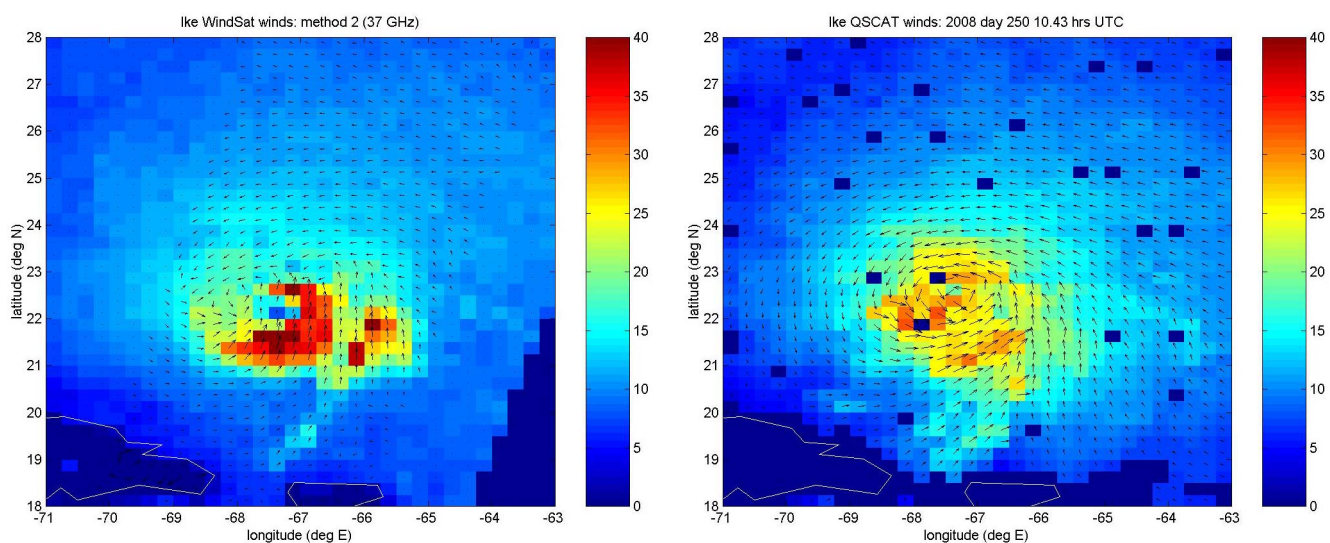
***Figure 4. Comparison of WindSat and QuikScat wind vectors for Hurricane Ike,
on 6 September 2008.***

Scatter plots of the WindSat versus QuikScat wind speeds are shown in Figure 5. In general, the
WindSat wind speeds are higher than the QuikScat winds at wind speeds over 20 m/s, but it is not clear
which of these is more accurate in this region. The correlation coefficient between the WindSat and
QuikScat wind speeds is 0.82, and the rms difference between these wind speeds is 3.1 m/s for
Hurricane Dean. For Hurricane Ike the correlation coefficient is 0.79 and the rms difference is 3.5 m/s.

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***Figure 5. Scatter plots of WindSat versus QuikScat wind speeds for Hurricane Dean (left panel)
and Hurricane Ike (right panel).***

An implicit comparison of the WindSat and QuikScat wind directions is shown by the scatter plots of
the *u* and *v* components of the wind velocity in Figures 6 and 7. The errors in these components seem
to be a more or less independent of the wind speed magnitude, which gives rise to an rms difference
between the wind directions that increases rapidly as the wind speed decreases. Thus, plots of the rms
error in the wind direction versus the wind speed give the perhaps misleading impression that the wind
direction accuracy degrades rapidly at low wind speeds.
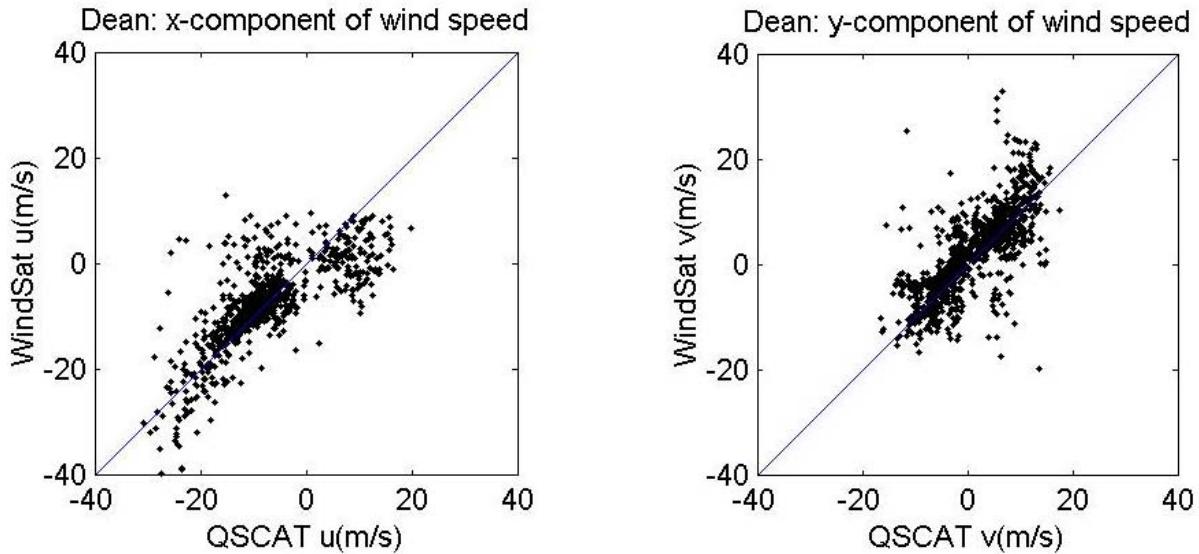
***Figure 6. Scatter plots of WindSat versus QuikScat wind vector components (u and v)
for Hurricane Dean.***

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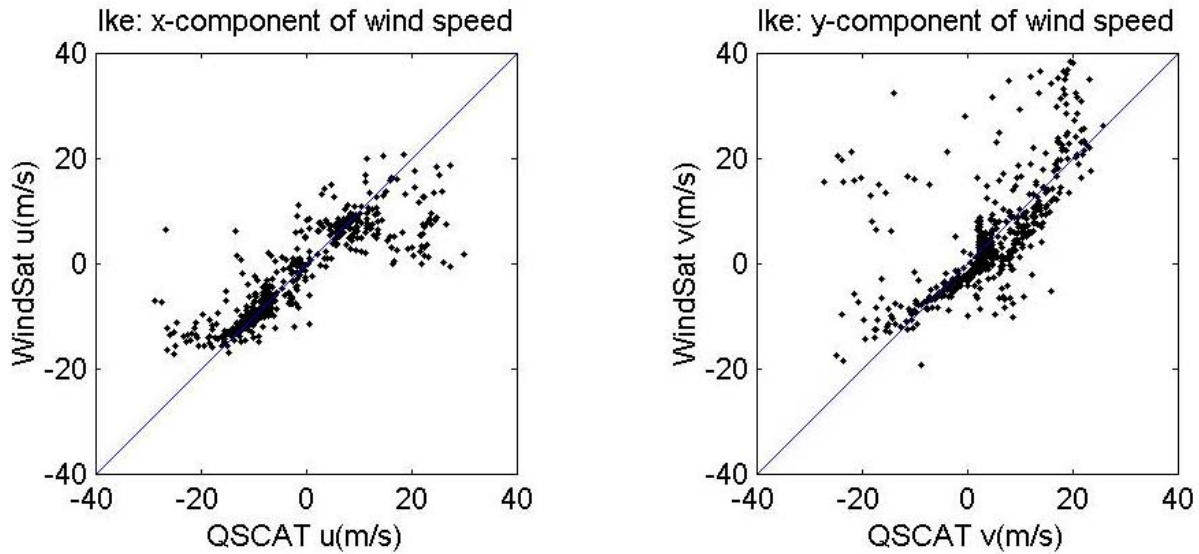
***Figure 7. Scatter plots of WindSat versus QuikScat wind vector components (u and v)
for Hurricane Ike.***

IMPACT/APPLICATIONS

The results of this investigation are expected to improve the efficiency as well as accuracy of wind vector estimates from WindSat data. The results should also be applicable to future satellite microwave radiometry systems.

RELATED PROJECTS

This investigation is potentially related to the ONR Interaction of Typhoon and Ocean Project (ITOP).

REFERENCES

Lyzenga, D.R., Comparison of WindSat brightness temperatures with two-scale model predictions, *IEEE Trans. Geoscience and Remote Sensing, 44*, 549-559, 2006 (DOI: 10.1109/TGRS.2005.857082).

PUBLICATIONS

Kim, D.-J. and D.R. Lyzenga, Efficient model-based estimation of atmospheric transmittance and ocean wind vectors from WindSat data, *IEEE Trans. Geoscience and Remote Sensing*, 46, 2288-2297, 2008.